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Annual energy saving potential for integrated application of phase change envelopes and HVAC in Western China

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Abstract

Recently, the application of the phase change materials (PCMs) in buildings has attracted more and more attention. To the authors' knowledge, little information is available in the opening literature on the integrated application of phase change envelopes (PCE) and heating, ventilation and air-conditioning systems (HVAC). For this purpose, the integrated application of PCE and HVAC are investigated based on EnergyPlus 8.6 on a typical residential building. The analysis is conducted in Kunming, Lhasa, Xi'an, Chengdu and Urumchi. Firstly, the effects of three different phase change temperature (PCT) on the energy savings of the HVAC buildings are analyzed for a whole year. Then, the optimal PCT are selected according to the annual energy savings. Meanwhile, the influence of the climate conditions on the energy saving rate are carefully analyzed. Lastly, the energy saving rate is also studied for both cooling and heating periods to evaluate the energy saving performance. These results highlight the potential of PCE in the HVAC buildings to decrease the energy consumption in Western China.

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Keywords: Phase change envelopes; HVAC; Energy saving performance; Western China; EnergyPlus

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Nomenclature

ρ	density, kg/m^3
c_p	specific heat capacity, J/(kg·ºC)
Δx	layer thickness of phase change envelopes Introduction, m
T	node temperature, ºC
λ	thermal conductivity, W/(m·K)
j+1	new timestep
j	present timestep
i	present node
i+1	adjacent node to interior of construction
i-1	adjacent node to exterior of construction λ thermal conductivity, W/(m·K)
Δt	timestep, s
h_i	phase change material's enthalpy, kJ·kg^{-1}
T_j	phase change material's temperature, ºC

1. Introduction

In the past decades, more than one-third of the total energy consumption in China comes from the building sector and approximately 65 % of energy consumption in buildings is due to HVAC systems [1]. It is estimated that without applying any energy efficient strategies, the energy consumption of buildings in China would account for more than 35 % of total primary energy use in 2020 [2]. Therefore, it is imperative to reduce HVAC energy use for the building sector. A fundamental measure to minimize the HVAC energy consumption is to strengthen the thermal performance of the building envelopes. To achieve the goal, different design strategies of energy saving are proposed, mainly containing active design strategies and passive design strategies. Based on the previous research, considering energy conservation and economic efficiency, passive strategies show larger advantages than active design strategies. Integrating PCMs into building envelopes is a potential passive method of reducing the HVAC energy consumption [3]. PCMs represents newly functional energy storage materials that could reduce peak loads and energy consumption in HVAC buildings.

Recently, in order to have a better understanding of the application of PCMs in buildings, several related investigations have been carried out and some useful research findings have been obtained. According to the experimental investigation, Kuznik et al. [4] found that the incorporation of PCMs into the building envelopes could remarkably reduce the peak temperature and the air temperature fluctuations in the light building envelopes. The findings showed that PCMs for the improvement of thermal comfort was very effective. Evola and Marletta [5] adopted the wallboards made of micro-encapsulated paraffinic PCMs to refurbish the existing lightweight buildings. They found that the PCMs storage/release efficiency is closely related with the position of the PCMs wallboards within the room, the rate of nighttime ventilation and the value of the peak melting temperature for the specific PCMs. In another study, EnergyPlus numerical simulation of a PCMs layer with specific properties and encased in between two layers of a building envelope was adopted to assess PCMs efficiency in relation to its placement, thickness and orientation. It was found that the optimal PCMs layer should be placed at the inner building envelope and the envelope orientation to the sun is very crucial for PCMs layer [6]. Saffari et al. [7] employed energy simulation software to analyze the energy performance of the PCMs incorporated in building models. PCMs with different melting points and layer thicknesses were studied for Madrid climate zone. In addition, payback analysis was also conducted to investigate the economic benefits of PCMs integration into the building envelopes. Marin et al. [8] established a numerical model and obtained the potential of using PCMs-enhanced gypsum boards in lightweight buildings, to increase the energy performance during both heating and cooling seasons in arid and warm temperate main climate areas.

These studies show that, the application strategies of PCMs based envelopes have been established and energy saving potential have been obtained. However, the effects of different climates on the energy consumption of the HVAC building with PCE have not been investigated. To the authors' knowledge, very few publications are available

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